

Polarimetric Imaging Laser Radar (PILAR) Program

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ABSTRACT

The US Air Force Research Laboratory has been developing the “Polarimetric Imaging Laser Radar” (PILAR) system. The purpose of the “PILAR” program is to demonstrate a 3-dimensional imaging laser radar sensor suitable for installation on an unmanned air vehicle (UAV). The program will demonstrate that such a sensor can be produced in a size and weight that is compatible with a UAV while maintaining sensor performance that meets mission requirements. The full system, a LADAR/MWIR/TV has been installed into a 15-inch turret. After a series of ground-based field trials and demonstrations, the necessary modifications will be made to the system in preparation for flight testing on a manned air vehicle. The goal of the PILAR program is to demonstrate a sensor that can produce 3-Dimensional images (including targets partially occluded by obscurants such as camouflage and foliage) at 0.3 meter (1 foot) resolution – equivalent to Digital Terrain Elevation Data (DTED) level VI, at ranges of up to 8 Km with area coverage rates in excess of 30 Km²/hr. as well as high-resolution terrain mapping. In addition to obtaining target shape information, the sensor will support collection of multiple returns and polarimetry data. This paper provides an overview of the program, a description of the hardware, current status, and future plans.

1.0 INTRODUCTION

The purpose of the PILAR program is to demonstrate a 3-D imaging laser LADAR sensor suitable for installation on a UAV. To meet the mission capabilities, the sensor must provide high-resolution 3-D imaging (including targets partially obscured by camouflage or foliage) and high-resolution terrain mapping. The PILAR program has been planned to quickly provide a sensor that meets or exceeds all program goals. The outcome of the program will be a fully functional sensor suite in a 15-inch turret (Figure 1-1). While the PILAR system consists of a MWIR camera, Day TV camera, and LADAR, the focus of the program has been in the design and integration of the LADAR into the turret.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 01 MAY 2005		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Polarimetric Imaging Laser Radar (PILAR) Program				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory AFRL/SNJM 3109 P Street Wright-Patterson AFB, OH 45433				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM202032., The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 34	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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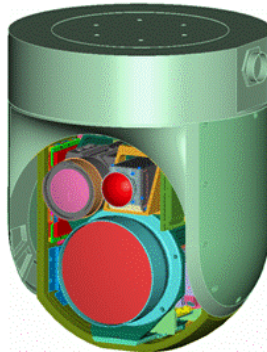
MWIR Camera

- MWIR InSb
- 320x240 Pixels
- WFOV: 11° H x 9° V
- MFOV: 2.2° H x 1.75° V
- 50/250 mm f/4.0



15-Inch Turret

- 3-Axis Gimbal
- Az: 360° Continuous, El +30°/-120°
- 98 lbs (turret), 45 lbs (payload)
- 28vdc, RS422



Sensor Controller

- Pentium 3 850 PC104+
- Serial Interface Board
- Diagnostic Display



LADAR Transmitter

- Wavelength = 1.064 μm
- Pulse Energy > 372 μJ @ 18.8KHz
- Pulse Width: 8 nsec to 12 nsec
- Beam divergence < 6mrad
- Beam Quality (M^2) < 1.5
- PRF From 17KHz to 25KHz



System Controller

- Rack Mounted, Ruggedized Chassis
- 3.06 GHz Pentium 4
- 120 GB Hard Drive
- RS-422/485
- 10/100 Ethernet
- DVD-RW Drive



LADAR Receiver

- Polarimetric
- 6-element receiver
- Single Mirror, 2-Axis Scanner
- > 6 km Performance
- 10 Hz, 90x90 Imaging
- < 50 μrad pixel spacing



CCD Camera

- Bandwidth: .4 - .7 μm
- Output Signal: RS-170



Figure 1-1: Overview of the PILAR System Hardware Currently Under Development.

The LADAR system design consists of several subsystems; the transmitter, the receiver, the optical system, the sensor electronics, and the system controller. The transmitter is an available compact, high pulse repetition frequency (PRF), solid-state laser. The optical system fully scans the laser to sample the target with the angular resolution needed to meet the spatial resolution requirement. The optical system's telescope provides the collecting aperture for the receiver. The receiver is a small array of avalanche photodiodes (APDs). For polarimetric imaging, an additional receiver array is added to the system. The sensor electronics control the laser, scanner, pulse signal processing, and all other sensor functions. In addition to these functions, it provides an interface to the system controller (located outside the turret).

The primary challenge to meeting the system requirements and mission capabilities is packaging the sensor in a 15-inch turret (Figure 1-2). Integrating advanced sensors into these types of gimbals presents several difficulties. Our approach takes these issues into consideration so that the follow-on activities to prepare the sensor for flight-testing do not require re-design of the sensor package.

Polarimetric Imaging Laser Radar (PILAR) Program

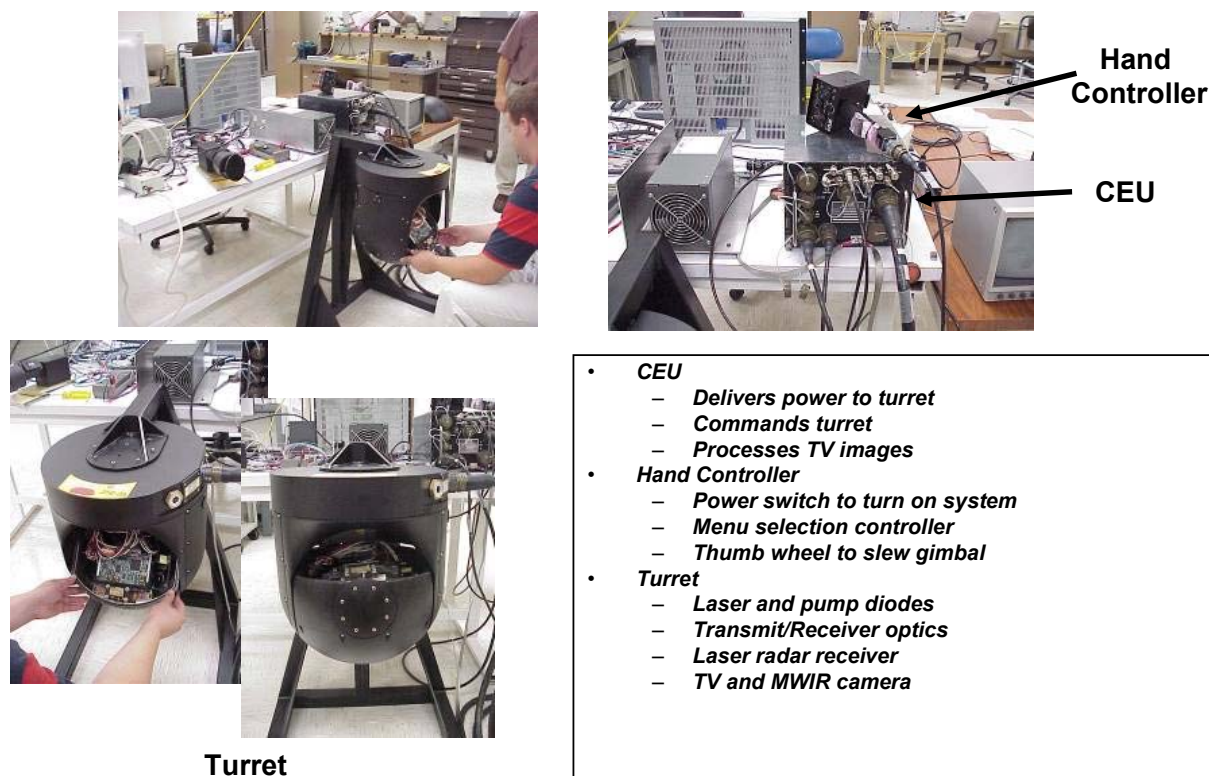


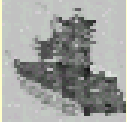

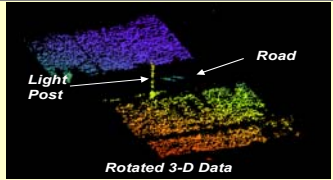
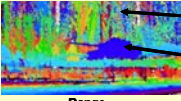



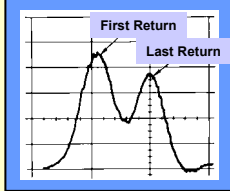
Figure 1-2: The Major Effort for the Program is to Integrate Existing LADAR Capabilities into a 15-Inch Turret to Demonstrate TRL 5 Performance.

1.1 LADAR Performance Requirements

In order to meet performance requirements, previous LADAR research and development efforts were leveraged. This approach was taken to reduce program schedule and technical risk because many of the requirements have been demonstrated with previously developed LADAR sensor systems. Some of these are shown in Table 1-1.

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Table 1-1: The Major PILAR Sensor Requirements Have Been Demonstrated During Several Previous LADAR Sensor Development Efforts.

Parameter	Requirement		<i>(All Images Collected With LADARs Developed By Lockheed Martin)</i>
	BASE	GOAL	
Wavelength (μm)	1.06	1.5	<p>The LADAR should operate at 1.06-microns, with a goal of 1.5-micron eye-safe operation.</p>  <p>1.06 Intensity</p>  <p>1.54 Intensity</p>
Laser Power (watts)	2-10		For UAV compatibility and packaging constraints within the 15-inch turret, the laser power should be reasonable.
System Power (watts)	< 500		To meet the UAV RSTA sensor power budget, the LADAR sensor power must be minimized.
Receiver Aperture (cm)	< 15		To meet the packaging constraints of a 15-inch turret, a reasonable aperture for the LADAR sensor was required.
Slant Range (m)	6000	8000	<p>To keep the UAV out of harms way (flying above 15,000 feet), the LADAR sensor must image beyond 6-km.</p>  <p>Rotated 3-D Data Ground-to-Ground Image (> 8km)</p>
Spatial Resolution (m)	0.33		<p>To provide high-resolution data for terrain mapping and target identification, the system requires 42 μrad angular resolution.</p>  <p>Range 15-cm Accuracy</p>  <p>1.5 μm Intensity 25 μrad Spatial Resolution</p>  <p>Range Fused With Intensity</p> <p>25 μrad Angular Pixel Spacing On A Target At 4400 Meters</p>
Frame Size (m)	30 x 30		With the required spatial resolution of 0.33-meter, the frame size translates into a 90x90 pixel image.
Range Accuracy (cm)	7.5		<p>To collect high-resolution 3-D data, the LADAR sensor must provide high accuracy, absolute range data.</p> 
Range Resolution (m)	< 1		<p>The detection algorithm approach must provide the capability to separate multiple returns. Range resolution is determined by the minimum resolvable distance between multiple returns.</p> 
Frame Rate (Hz)	10		To meet the 10 Hz imaging requirement for a 90x90 image, the LADAR sensor is required to collect more than 81,000 pixels/second.
Object Location Accuracy (m)	1		<p>A long range system requires very accurate position data and angular measurements for meeting this requirement. This requires turret pointing error reduction and improved positional data from the UAV. Since these are "fixed", we need to look at operational concepts, such as an inertial track function integrated with 3-D tracking algorithms to reduce the TLE.</p>

2.0 LADAR SYSTEM DESIGN

The LADAR system design was first assembled in the breadboard layout shown in Figure 2-1 and consists of several subsystems; the transmitter, the receiver, the optical system, and the sensor electronics. The transmitter is an available compact, high PRF, solid-state laser. The optical system fully scans the laser to sample the target with the angular resolution needed to meet the spatial resolution requirement. The optical system's telescope provides the collecting aperture for the receiver. The receiver is an array of avalanche photodiodes (APDs). For polarimetric imaging, an additional receiver array was added to the system. The sensor electronics control the laser, scanner, pulse signal processing, and all other sensor functions. In addition to these functions, it provides an interface to the system controller (located outside the turret).

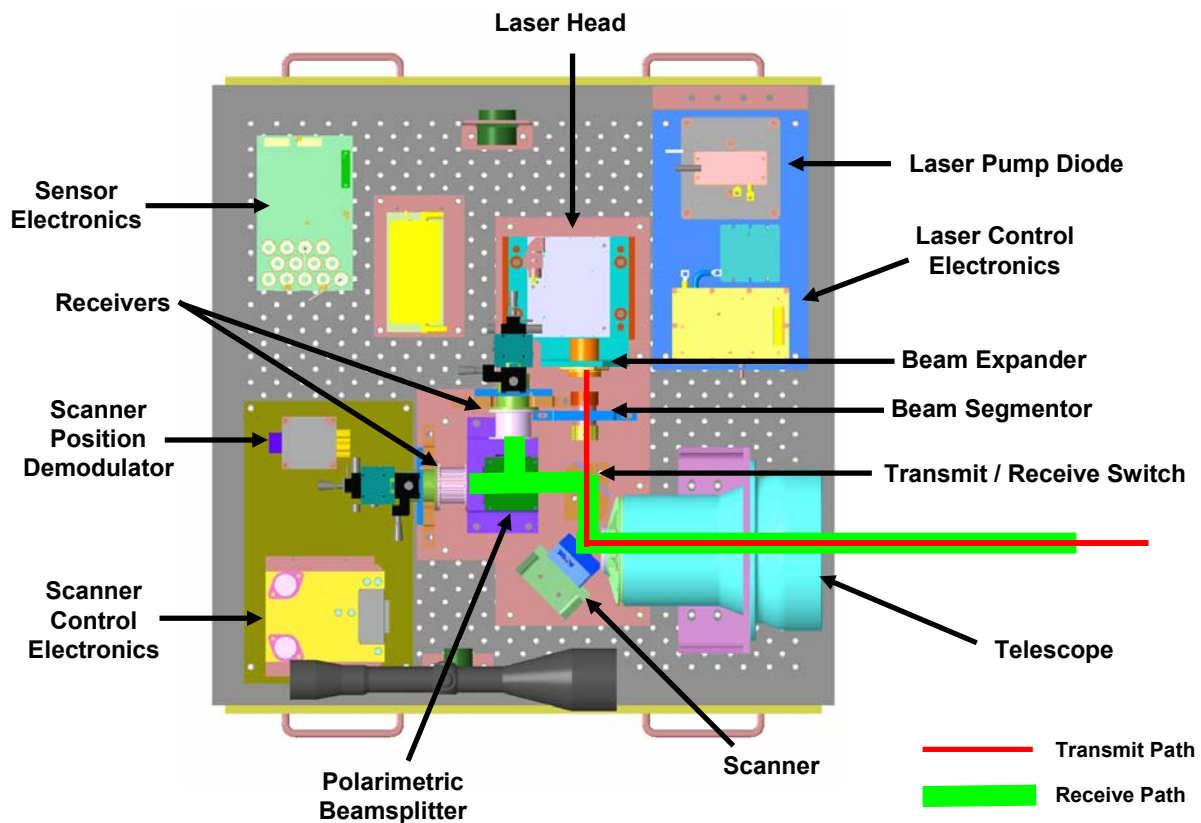


Figure 2-1: The Risk Reduction Breadboard Layout for the PILAR LADAR Sensor.

To achieve the pixel data rate necessary to meet the system frame size and frame rate requirements, our two-axis scanned, high PRF transmitter approach is coupled with a 6-element linear array receiver design. The receiver is co-aligned with the transmitter using a transmit/receive switch (holed mirror) prior to the scan mirror. The receiver consists of a narrow band filter, imaging lens, and the detector array. The imaging lens is diffraction limited to insure all the received energy is focused on the detectors. The return laser pulse is split between the two channels by a polarizing beam splitting cube.

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2.1 Transmitter

Laser. The selection of the laser transmitter is primarily driven by the system range requirement and the derived pixel data rate requirement. The laser developed by BAE Systems, is a diode pumped solid-state Q-switched device. It operates within the required wavelength, provides the necessary pulse energy, and meets the laser power requirement. To achieve a 10 Hz frame rate, the system pixel data rate must exceed 81,000 pixels/second. Our selection of an 18 kHz PRF laser with a 6-element receiver provides a 108,000 pixels/second data rate.

Beam Expander. The system requires a low beam divergence to meet the spatial resolution requirement of 0.33 meters at 8 km. This required a beam expander design with a magnification between 15X and 18X. A standard two-element beam expansion design was not adequate; our beam expander is a four-element design.

Beam Segmentor. The receiver design is a 6-element fiber bundle array. This required the design of a beam segmentor to match the receiver.

2.2 Receiver

Polarimetric Beam Splitter. The system has two receivers. This is required to meet the polarimetric data collection capability. A polarimetric beamsplitter is used to split the return beam into the two receivers to separate the polarizations.

Receive Lens Assembly. The PILAR system narrow IFOV requires a long focal length (> 200 mm). However, the packaging in the 15-inch turret demands a shorter lens track. In our baseline design the lens track was reduced by 2X with a 3-element telephoto design.

Fiber Bundle Array. The receive array is actually a bundle of fiber optics; each connected to a discrete detector. There are actually seven fibers. The extra fiber feeds the “back scatter” detector to provide the time at which the laser pulse actually departs the system. This is required to remove the laser fire jitter to accurately compute the laser time of flight.

Detector. The detectors are silicon avalanche photodiode (APD) made using a double-diffused “reach through” structure. These photodiodes are designed such that their long wave response ($\lambda > 900$ nm) has been enhanced. The APDs do not have an integrated preamp. A low-noise amplifier is being used on the receiver board to provide signal gain.

2.3 Optical System

The optical system provides the means to transmit and receive laser pulses. The large aperture allows long range imaging, exceeding the program requirement, with the available transmitter and receiver. The optical system also generates the angular resolution required to meet the spatial resolution requirement by controlling beam divergence and utilizing a single mirror, two-axis scanner. The scanner provides the speed to meet the 10 Hz frame rate requirement.

Telescope. It was required that the receiver aperture diameter be less than 15-cm. This is crucial to ensure that the sensor could be integrated into a 15-inch turret. The telescope is a refractive Galilean with 6X magnification. The basic design parameters are:

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- Aperture < 6" Diameter
- Field Angle > 0.35 Degrees
- Transmission > 92%

Two-Axis Scanner. A single frame 90-pixel by 90-pixel image is required. With our two-axis scanned, small array approach, the image frame size is controllable, giving us the capability to meet this frame size requirement. The scanner speed is adequate to meet the 10 Hz frame rate requirement with 70-percent scan efficiency. The two-axis scan approach allows the sensor can collect variable frame sizes if desired due to the flexibility provided by the scanning approach.

2.4 Electronics

Our sensor controller consists of PC/104 format electronic boards. These have been proven to work in operational environments, are commercially available, and minimize the impact on the overall sensor size, weight, and volume. The sensor electronics communicates with the LADAR electronics via a custom serial interface board. The LADAR electronics is a three-board consisting of the Polarimetric Receiver Electronics (PRE), the Polarimetric Data Combiner (PDC), and the Pulse Capture Electronics (PCE). These are discussed in the following paragraphs.

Polarimetric Receiver Electronics. For polarimetric data collection, the system requires detector pairs to be aligned to collect the two polarization channels. Each pair of detectors images the same pixel, but receives a different amount of energy depending on the polarization of the return signal. The PRE board receives thirteen optical inputs via fiber (6 pairs plus backscatter). The optical inputs are connected to avalanche photo diodes (APDs) that convert optical power (watts) to electrical current (amps). A low-noise transimpedance amplifier is used to convert the current to voltage. The thirteen analog signals (voltages) are sent to the polarimetric data combiner board.

The fundamental purpose of the PRE is to capture the signals received from the return laser pulses. For polarimetric data collection, it is critical that the signals be normalized. An attenuator is used to reduce the signal level during the outgoing laser pulse time. This keeps the energy of the backscatter below the saturation level of the electronics, allowing us to use this signal to match the gains of the channel pairs. The gain matching is accomplished using the voltage controlled amplifiers. In addition, the bias of each APD is set individually and each is temperature controlled.

Polarimetric Data Combiner. The combiner board provides the polarimetric peak detection logic and sums the detector pair outputs prior to range processing. The peak detector holds the intensity data for capture. The peak values provide the polarimetric information. In addition, this board monitors the backscatter energy on each channel. This data is used to control the gain on the channel pairs. The main function of this board is to provide a peak detector to hold the intensity data for capture by an Analog to Digital Converter (ADC).

In order to recover some of the lost range performance from the splitting of the return signal, the channel pairs are summed prior to sending the data to the PCE. This is done using a low-noise summing amplifier.

Pulse Capture Electronics. Our signal processing approach for analyzing return laser pulses implements a well-established direct detection algorithm. This algorithm has been used in several ground, tower, and airborne LADAR programs. Its function is to accurately determine time of flight (absolute range) and relative

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reflectivity (intensity) under varying conditions of range, reflectivity, atmospheric attenuation, obliquity, multiple returns and noise. This signal processing approach provides a proven method to meet the range accuracy and range resolution requirements, as well as providing the capability to resolve multiple returns to see through foliage and camouflage nets.

This signal processing approach continuously digitizes and processes the detector output in real-time. The return signal is captured and stored in memory. The data is passed through a convolution peak detector function to extract the pulse position from the data. The entire captured pulse is used to minimize the effects of signal strength variation, noise and distortions. A programmed template, designed to match the nominal pulse shape, is convolved with the data in steps of 2X the sample rate (U.S. Patent 6,115,113). When the data most accurately matches the template, the convolver output is at a maximum, giving the pixel's absolute range. The maximum convolver output value at this point is proportional to the return pulse energy. Because many data samples are used at each template step to generate the convolver's output, available signal-to-noise is used to best advantage.

2.5 Sensor Controller

The sensor controller software heavily leverages the LADAR control software developed for a LADAR IR&D test-bed to reduce program schedule risk. The software communicates with the PRE, PDC, and PCE. The software consists of the Server Process, LADAR Interface, Serial Interface Board Driver (SIBD, and Diagnostic Display Driver. The Server Process communicates with the System Controller through HTTP requests and responses over Ethernet interface. It also assesses commands to the LADAR Interface. The LADAR Interface polls the server process for work to do, receives and processes commands from server process, returning status and data, calls the SIBD to transmit to the LADAR Electronics, polls SIBD for received data, returns status and diagnostic data to server process, and writes LADAR data to a file or memory object. The SIBD runs in background and handles requests to write to and read from the LADAR electronics. The Diagnostic Display Driver communicates with the Server Process for diagnostic and status information and writes to the LCD screen.

2.6 System Controller

Our system controller is a rack mounted personal computer (PC). It is a Windows based operator interface that includes on-screen control of the sensor system, as well as displaying the collected data. The core software is written in ANSI C / C++ so that it can easily be hosted on other platforms. This provides a surrogate for the hardware that might eventually be installed in a UAV. The system controller interfaces with the sensor system, the gimbal, and the (potential) UAV.

3.0 PROGRAM STATUS

The risk reduction breadboard was integrated and used to check-out electronics and debug software prior to turret integration. The integrated prototype was delivered in November 2004 to AFRL. Work has begun on the efforts necessary to prepare the turret for flight testing mid-year 2005.

3.1 Risk Reduction Breadboard

The risk reduction breadboard is shown in Figure 3-1. The primary purpose of the breadboard was to provide a method to check out electronics and software prior to turret integration. In addition, it will provide spare parts in the event that any piece of the integrated turret prototype fails.

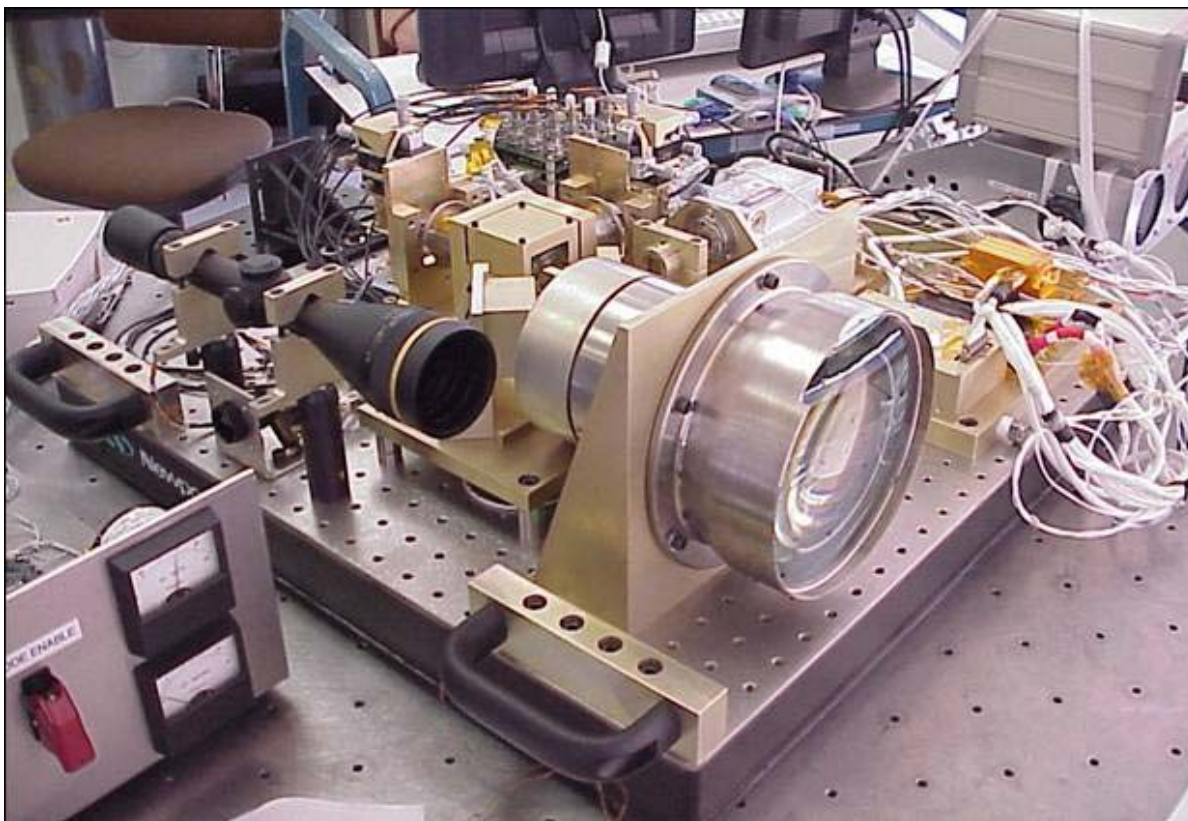


Figure 3-1: The PILAR Risk Reduction Breadboard is Being Used to Debug Hardware and Software Prior to Turret Integration.

The breadboard also provides AFRL with a “second system” for data collections and further risk reduction activities. This is crucial since the turret hardware will be unavailable for data collection activities in early 2005 due to the minor modifications it will undergo to prepare it for flight testing.

Integrated Turret Prototype

After the hardware and software was functional on the breadboard, turret integration began. Figure 3-2 shows a drawing of how the components are organized within the 15-inch turret.

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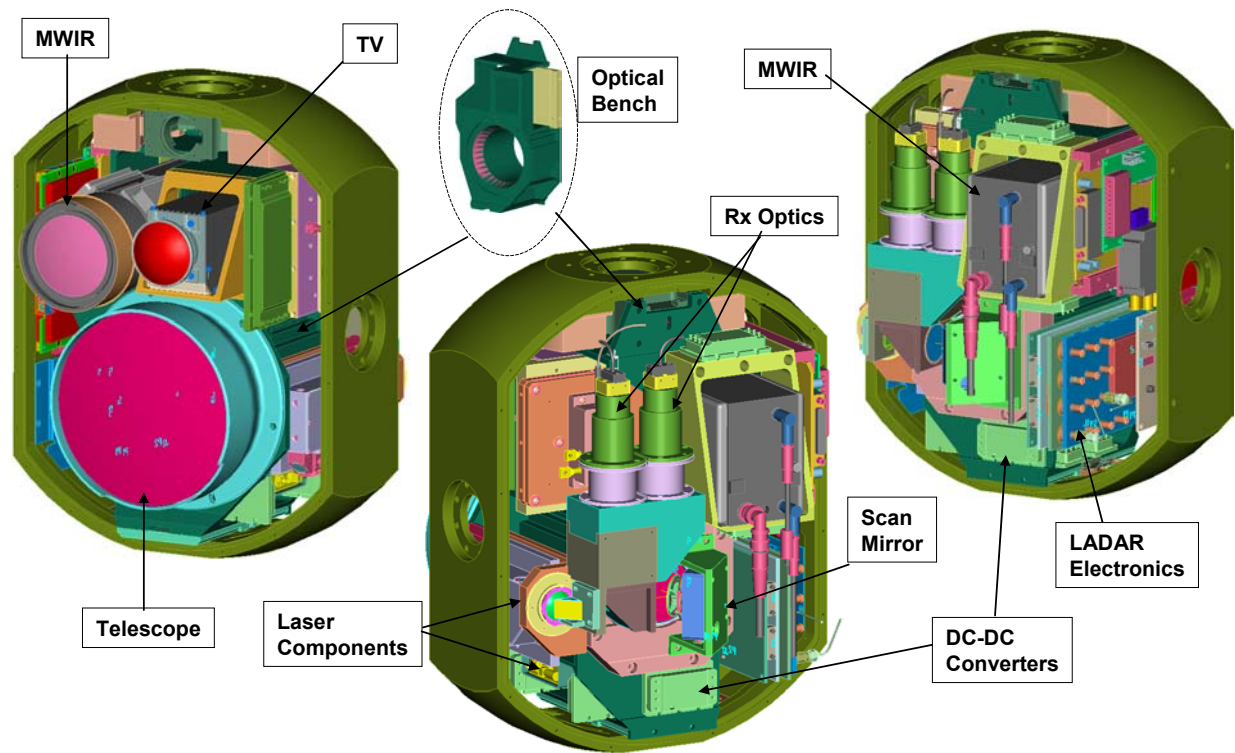


Figure 3-2: Conceptual Drawing of the Integrated Sensor Suite for the PILAR System.

4.0 TEST RESULTS

During initial testing at WPAFB, a number of structures visible from the tower laboratory were imaged. One such structure is an expandable side semi-trailer. The system was easily able to image that target. Figure 4-1 illustrates the data collected from that trailer. In this image, range is represented by color with blue representing a closer range shifting towards red as the range increases. The white line in the picture illustrates the line-of-sight from the sensor. The shape of the trailer, including the expandable sides are clearly visible.

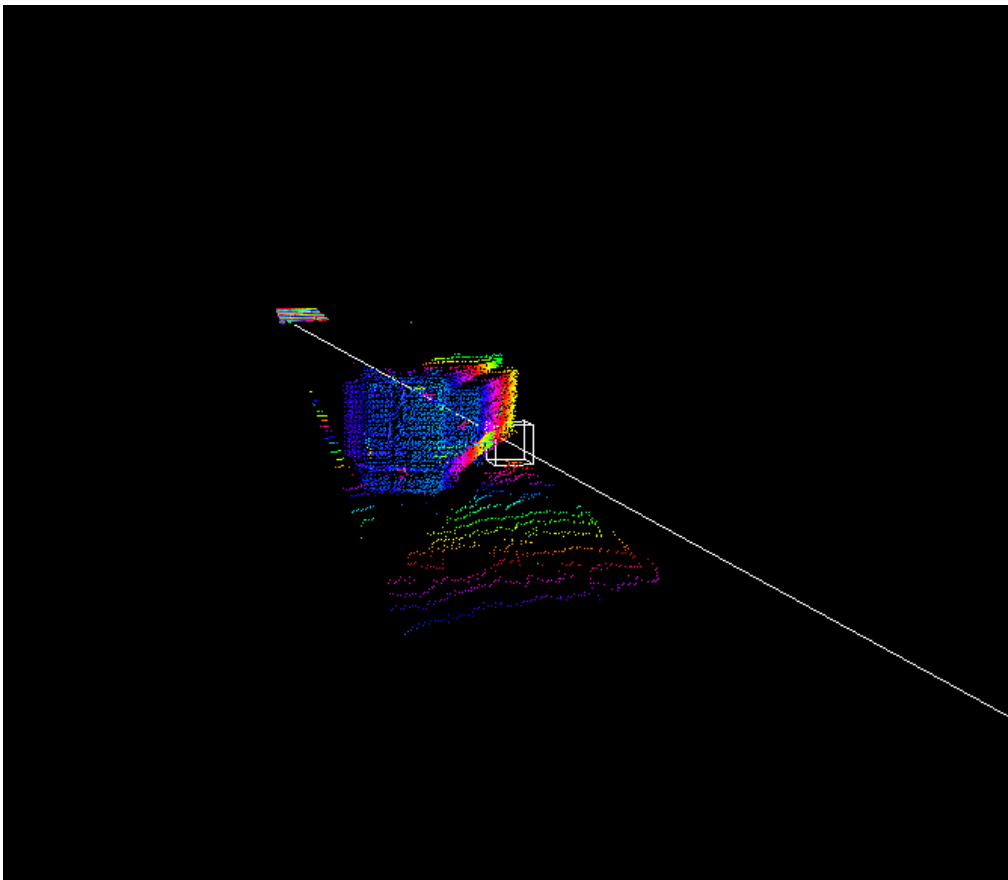


Figure 4-1: Semi-Trailer imaged with PILAR.

A second target was a water tower at over 5000 meters. Images of that target are shown in Figure 4-2. Here, the 2 views show the tower nearly head on and from the side. The nature of 3-D data allows these images to be rotated using simple coordinate transformations. The cylindrical shape of the tower can be clearly observed in these views.

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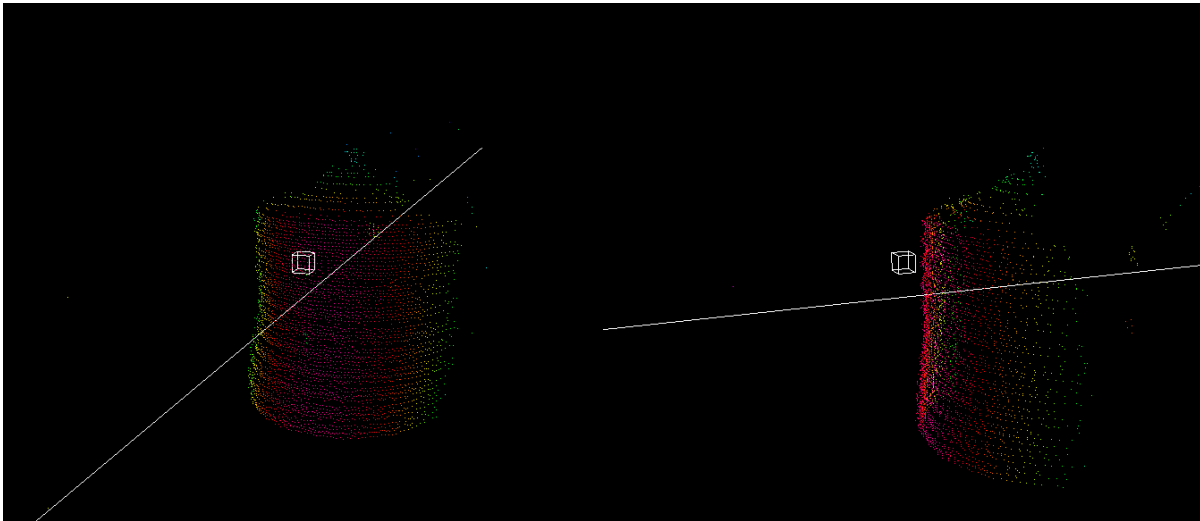


Figure 4-2: Water tower rotated approximately 90 degrees.

5.0 FUTURE EFFORTS

5.1 Aircraft Integration

The PILAR turret is being mounted onto the surrogate UAV platform (Figure 5-1) using a quick disconnect mount assembly. The mount is fixed to a plate integrated into the aircraft's adjustable equipment bay. This mounting fixture will allow us to quickly integrate the turret to the aircraft for flight testing. Modifications already made to the aircraft allow protrusion of the PILAR system.

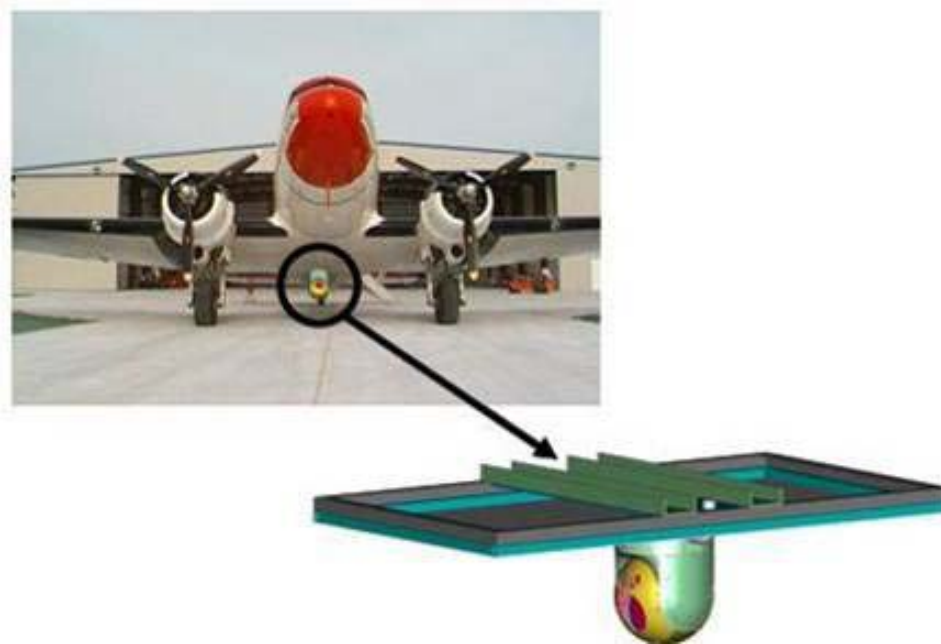


Figure 5-1: Conceptual Drawing of the PILAR System Integrated on to the Surrogate UAV Platform.

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In order to maintain the availability of the PILAR sensor for other data collections, the majority of the control system will be duplicated. The duplicate components of the flight test console will be integrated into the aircraft's existing internal equipment racks. The cable harnesses fabricated for the flight test console will be of sufficient length for integration into the aircraft's rack structure.

5.2 Flight Testing

After integration and initial check-out of the system are completed, a number of flight missions are planned for the system. Preliminary plans call for missions over a variety of target area types. These areas include: urban, industrial and residential sites; forested and coastal areas, as well as military type sites. The purpose of these missions will be, not only to demonstrate the performance of the sensor, but to begin establishing a laser radar imagery database that can be used to assist the development of algorithms and processes for extracting and visualization of information from these types of data.

6.0 SUMMARY

The sensor will collect true 3-D data of fine resolution (angular and range) to provide the capabilities for high-resolution imaging and generate high-resolution terrain maps. More importantly, our sensor solution provides all the necessary functionality to meet the requirements outlined in Section 1.1 and the capabilities discussed in Section 1.2.

High-Resolution 3-D Imaging. The optical system and pulse capture electronics provide true 3-D data to enable high-resolution imaging. The optical system uses the fast, two-axis scanner to "raster scan" the area of interest. The 6-element receiver and 18 kHz PRF laser provide the required data rate to generate a 10 Hz stream of 3-D images to the system controller.

Imaging of Targets Partially Obscured by Camouflage or Foliage. Lockheed Martin's highly successful pulse signal processing technology is being exploited to provide a robust signal processing approach for PILAR. The ability of this signal processing approach to resolve multiple returns provides the required capability for imaging targets that are obscured by camouflage nets and foliage.

High-Resolution Terrain Mapping. The LADAR sensor, controlled in coordination with the turret, provides the necessary capability to collect ground scans of high accuracy / high resolution 3-D data suitable for terrain mapping. The scan pattern will be a function of the LADAR capabilities, turret parameters, aircraft altitude, and aircraft speed.

Polarimetry Information. The addition of a second receiver and a beamsplitter provides the LADAR sensor the capability to collect polarimetric data. While splitting the receive beam reduces overall range performance, the detector outputs are "re-combined" after the polarimetric peaks are found to recover some of the lost signal.

UAV Size and Weight Compatibility. The primary challenge to meeting the system requirements and mission capabilities is packaging the sensor in a 15-inch ball turret. The integrated prototype being developed will show that it is feasible to have a multi-sensor RSTA system that includes a LADAR sensor.



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7.0 ACKNOWLEDGEMENTS

The authors would also like to thank the dedicated engineering staff at Lockheed Martin Missiles and Fire Control for their efforts in developing and integrating the hardware.



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PILAR Program Overview

OBJECTIVE: *The objective of the PILAR program is to demonstrate a 3-D imaging LADAR sensor suitable for installation on a UAV.*

GOAL: *The goal of the PILAR program is demonstrate include high-resolution 3-D imaging (including targets partially occluded by obscurants such as camouflage and foliage) and high-resolution terrain mapping with the PILAR sensor. In addition to obtaining target shape information, the sensor will support collect multiple returns and polarimetry data.*



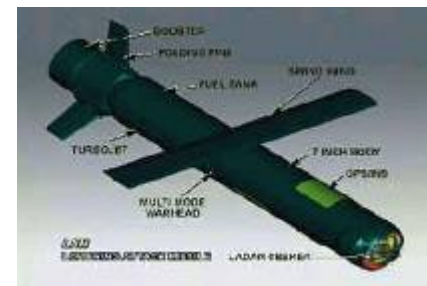
Program Goals

<i>Parameter</i>	<i>Goal</i>
<i>Wavelength (microns)</i>	1.06 (1.5 preferred)
<i>Laser Power (watts)</i>	2-10
<i>System Power (watts)</i>	< 500
<i>Receiver Aperture (cm)</i>	< 15
<i>Slant Range (m)</i>	> 6000
<i>Spatial Resolution at 8km (m)</i>	0.33
<i>Minimum Frame Size (m)</i>	30 x 30
<i>Range Accuracy (cm)</i>	+/- 7.5
<i>Range Resolution (m)</i>	< 1
<i>Frame Rate (Hz)</i>	10
<i>Object Location Accuracy (m)</i>	1



System Heritage

- ***PILAR Electro-Optic Design Is Based On:***
 - ***LOCAAS LADAR Seeker (Current)***
 - ***NLOS (NetFires) LADAR Seeker (Current)***
 - ***TRACER/FSCS Long Range LADAR (Current)***
 - ***Polarimetric Breadboard LADAR (Circa 1990)***
- ***The PILAR System Will Have:***
 - ***Long Range***
 - ***High Resolution***
 - ***High Frame Rate***
 - ***Polarimetric Capability***



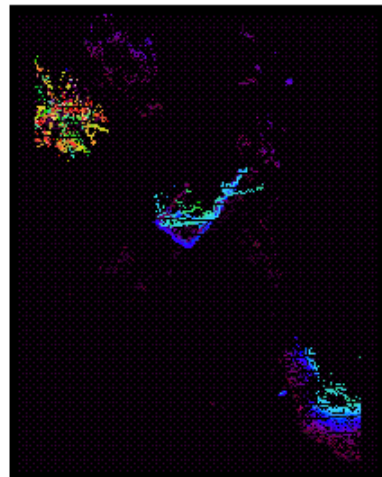
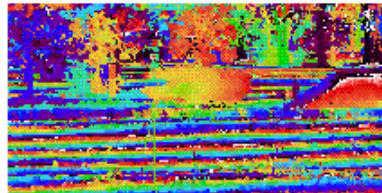
All Of The Program Requirements Had Been Met Or Exceeded In Previous Systems ... In The PILAR Program We Are Bringing These Pieces Together.



Objective: 3-D Imaging

The LADAR Sensor Must Collect High Resolution 3-D Images

Target Identification



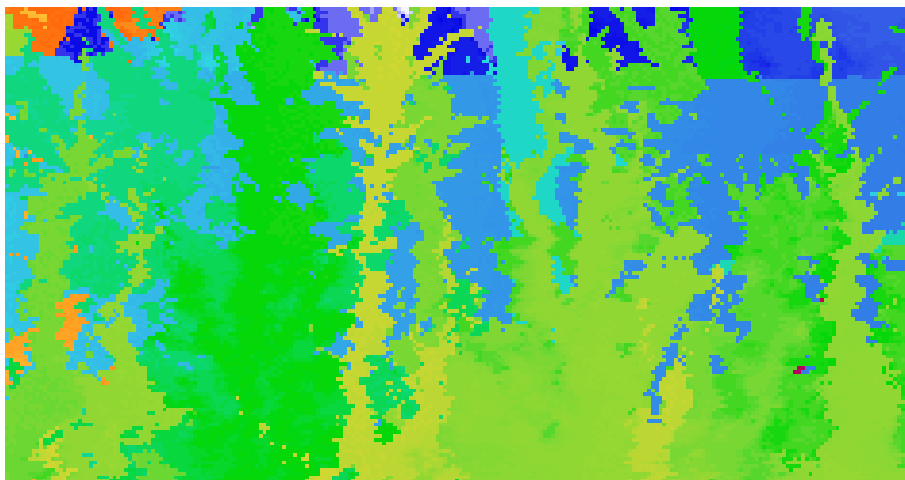
Segmentation



Objective: Multiple Returns

The Pulse Processing Approach Must Allow Multiple Returns To Be Separated For Imaging “thru” Foliage and Camouflage

Wall Behind Foliage

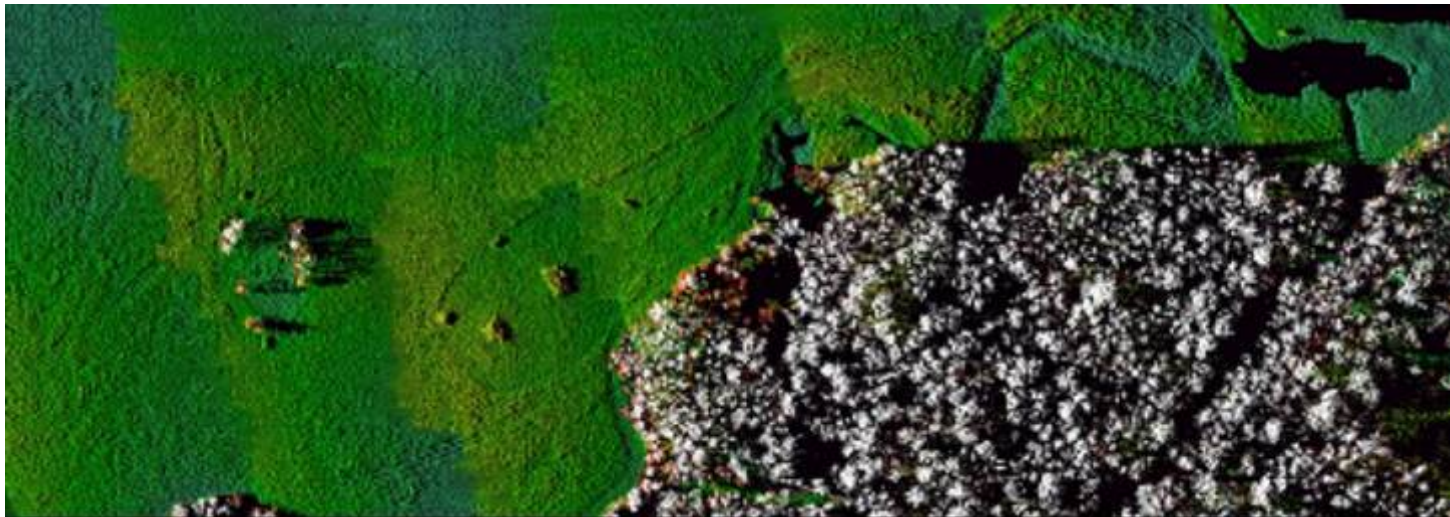


Best Pulse



Objective: Terrain Mapping

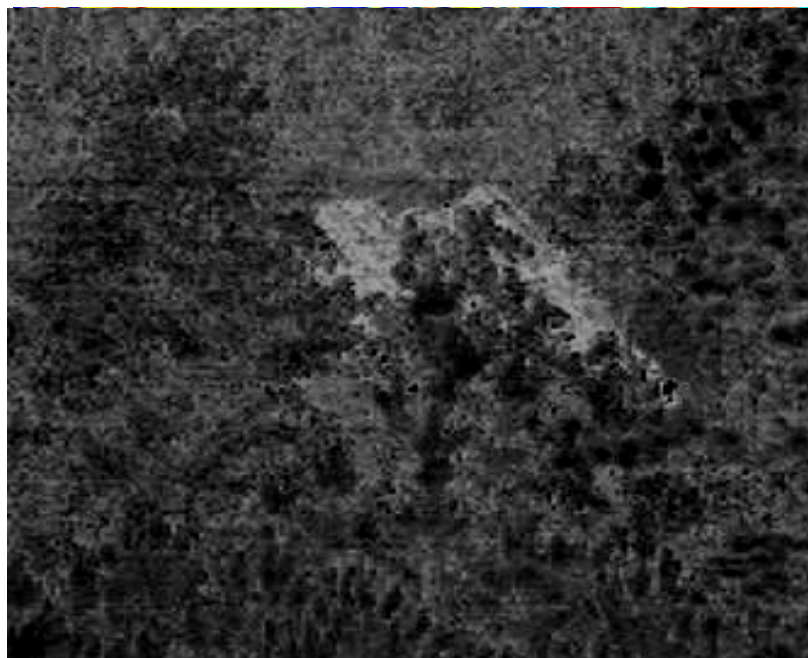
The System Approach Must Provide The Flexibility To Collect High-Resolution Data Suitable For Generating Terrain Maps





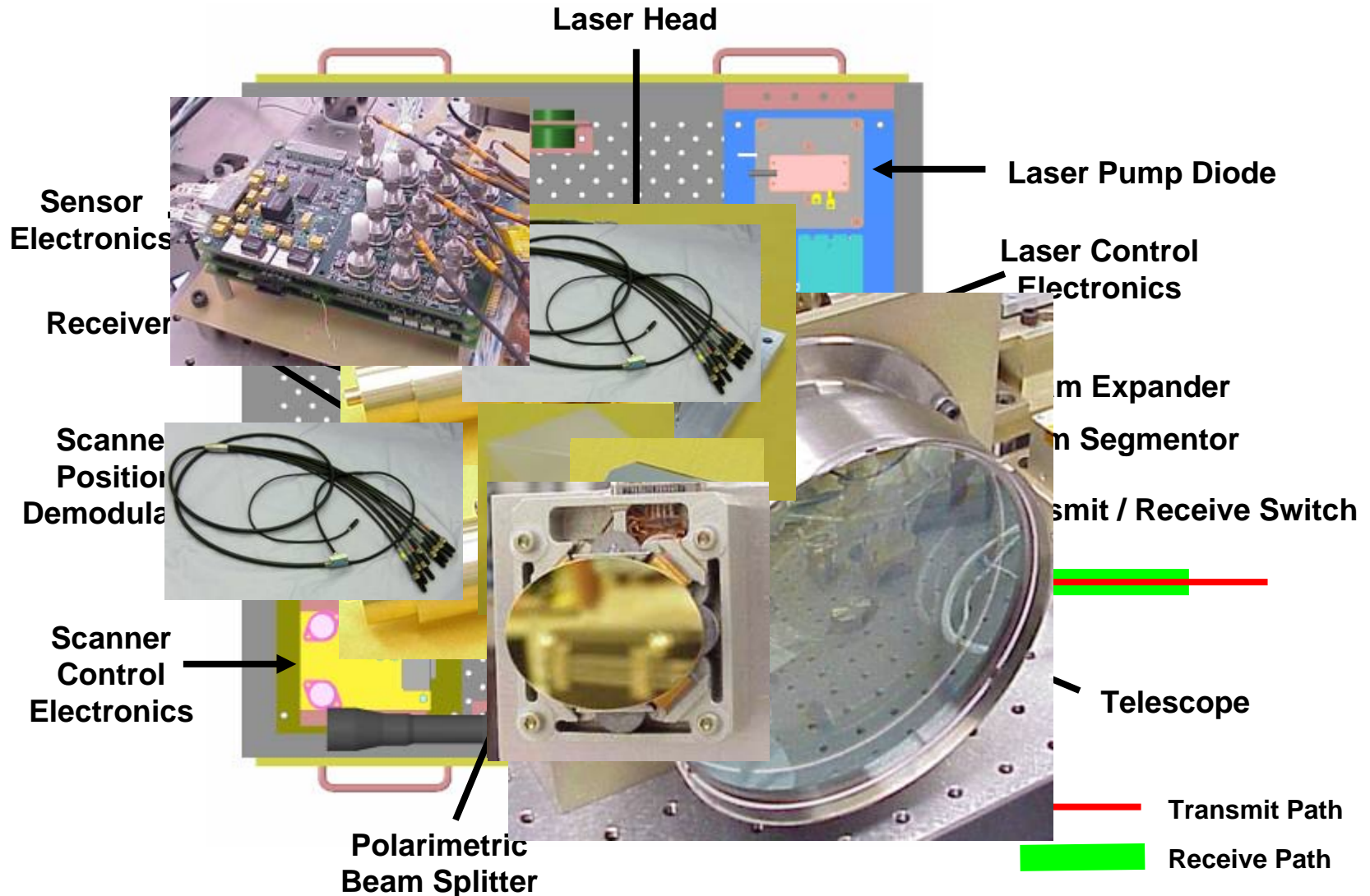
Objective: Polarimetry

**The Receiver Approach Must Provide The Data Necessary
For The Detection Of Man-Made Objects In Cluttered
Environments Using Polarimetric Information**



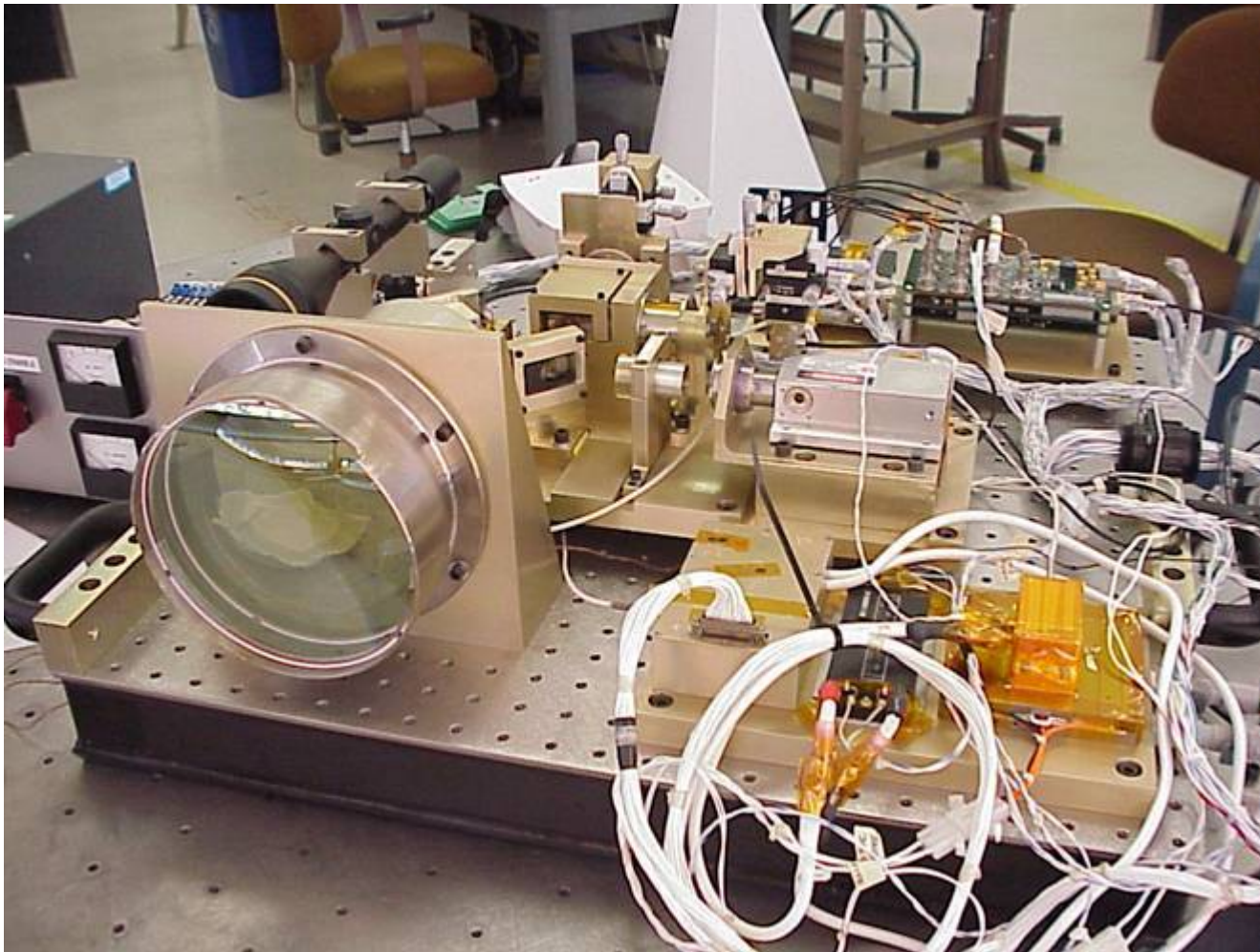


Risk Reduction Breadboard





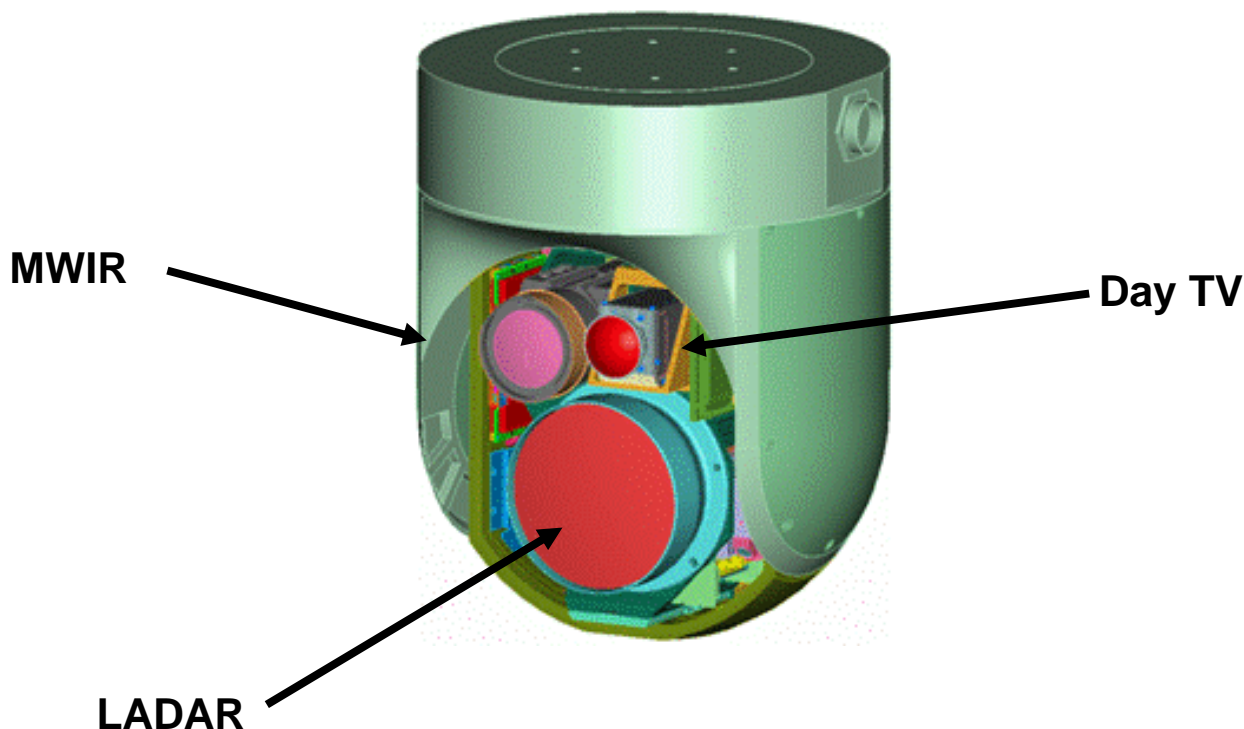
Risk Reduction Breadboard





Objective: UAV Compatibility

The Primary Challenge To The Program Goals Was Packaging The Sensor In A 15-Inch Ball Turret, With Other Sensors, To Make A Robust Sensor Suite Suitable For UAV Installation





PILAR Components

MWIR Camera

- MWIR InSb
- 320x240 Pixels
- 50/250 mm f/4.0



LADAR Transmitter

- Wavelength = 1.064 μm
- Pulse Energy > 372 μJ @ 18.8KHz
- Pulse Width: 8 nsec to 12 nsec
- PRF From 17KHz to 25KHz



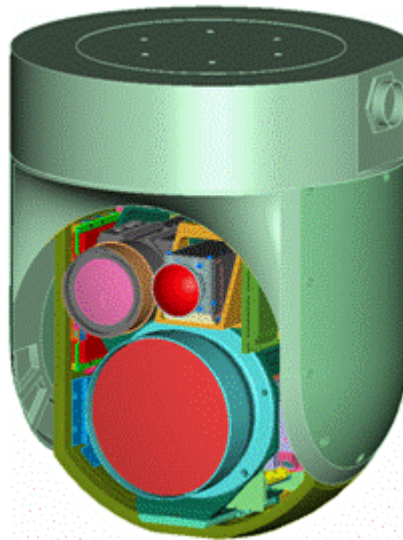
LADAR Receiver

- Polarimetric
- 6-element receiver
- Single Mirror, 2-Axis Scanner
- > 6 km Performance
- 10 Hz, 90x90 Imaging
- < 50 μrad pixel spacing



15-Inch Turret

- 3-Axis Gimbal
- Az: 360° Continuous, El +30°/-120°
- 98 lbs (turret), 45 lbs (payload)
- 28vdc, RS422



Sensor Controller

- Pentium 3 850 PC104+
- Serial Interface Board
- Diagnostic Display



System Controller

- Rack Mounted, Ruggedized Chassis
- 3.06 GHz Pentium 4
- 120 GB Hard Drive
- 10/100 Ethernet
- DVD-RW Drive



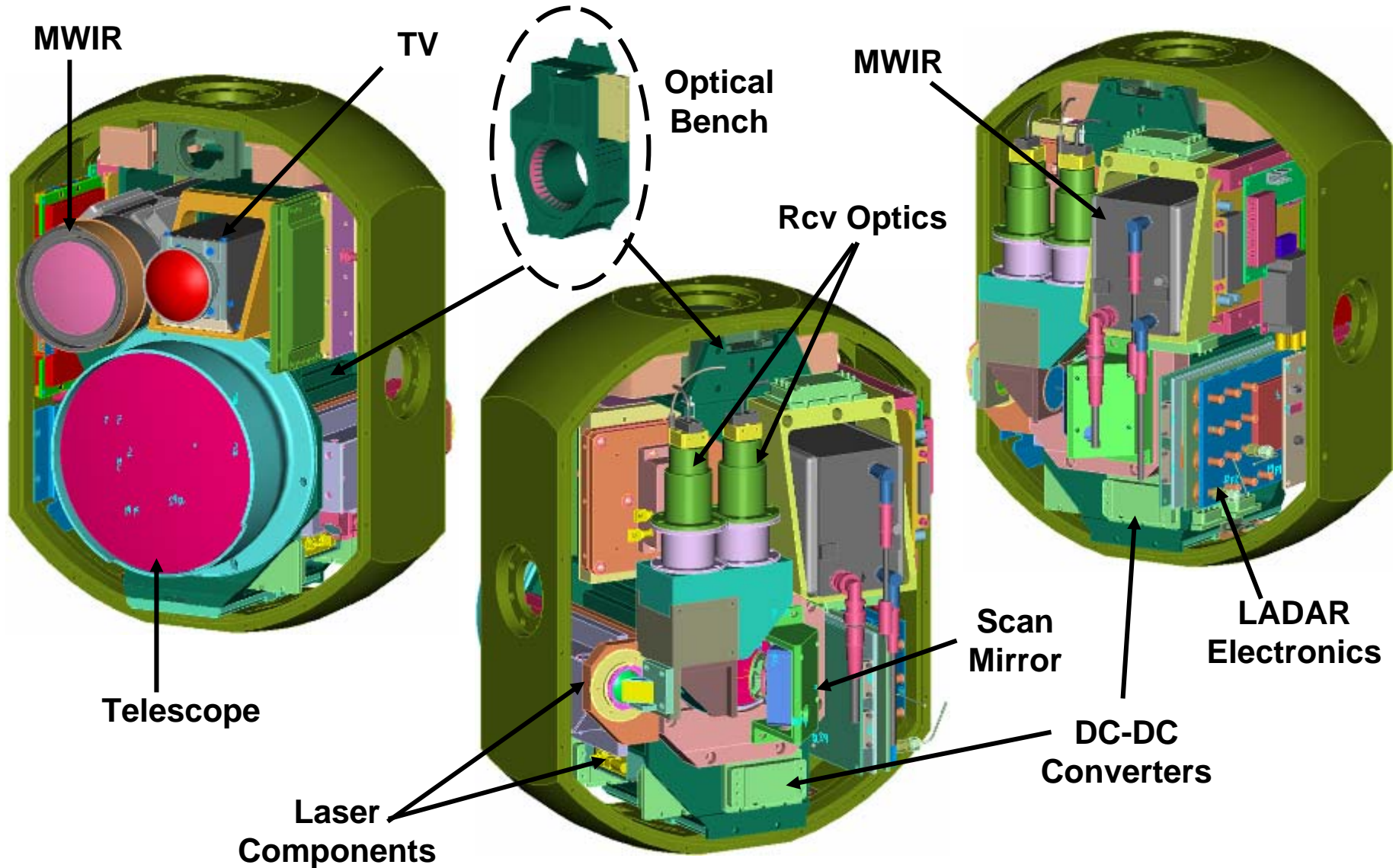
CCD Camera

- Bandwidth: .4 - .7 μm
- Output Signal: RS-170



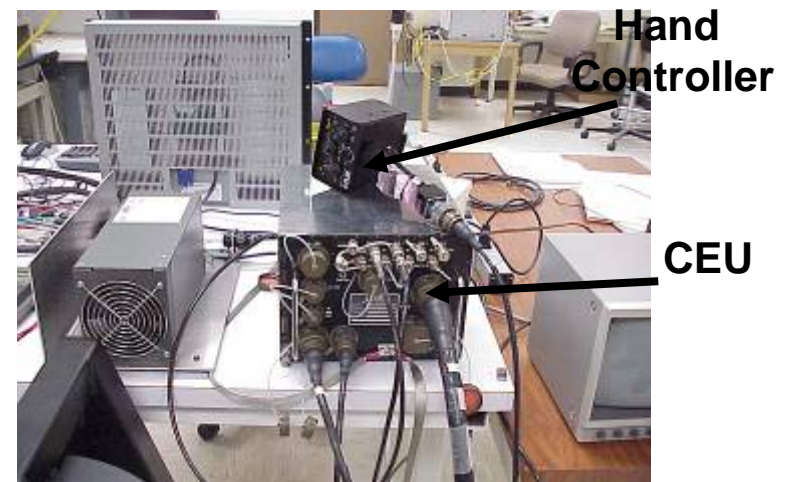


Turret Packaging





Turret and Electronics

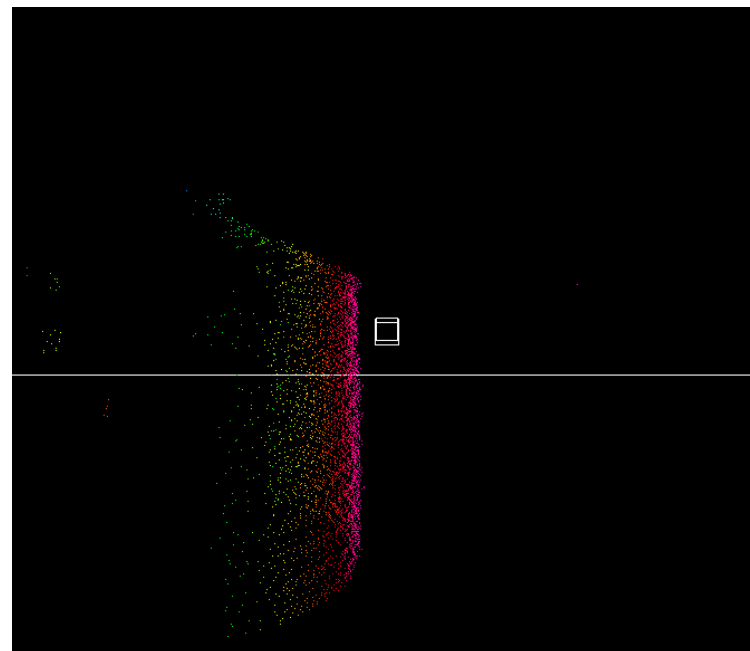
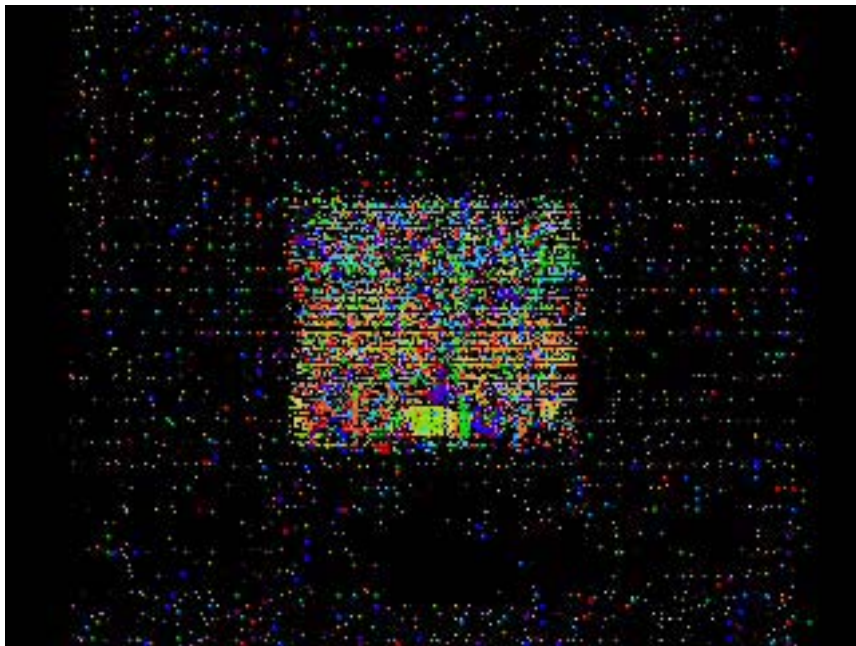


Turret

- **CEU**
 - Delivers power to turret
 - Commands turret
 - Processes TV images
- **Hand Controller**
 - Power switch to turn on system
 - Menu selection controller
 - Thumb wheel to slew gimbal
- **Turret**
 - 3-D Ladar
 - Vis and MWIR cameras

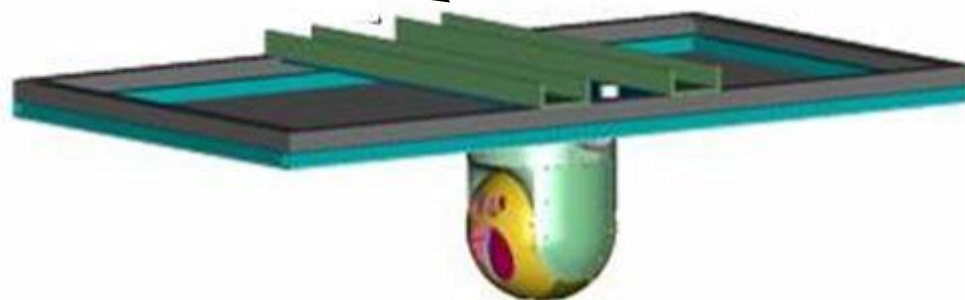


Sample Images





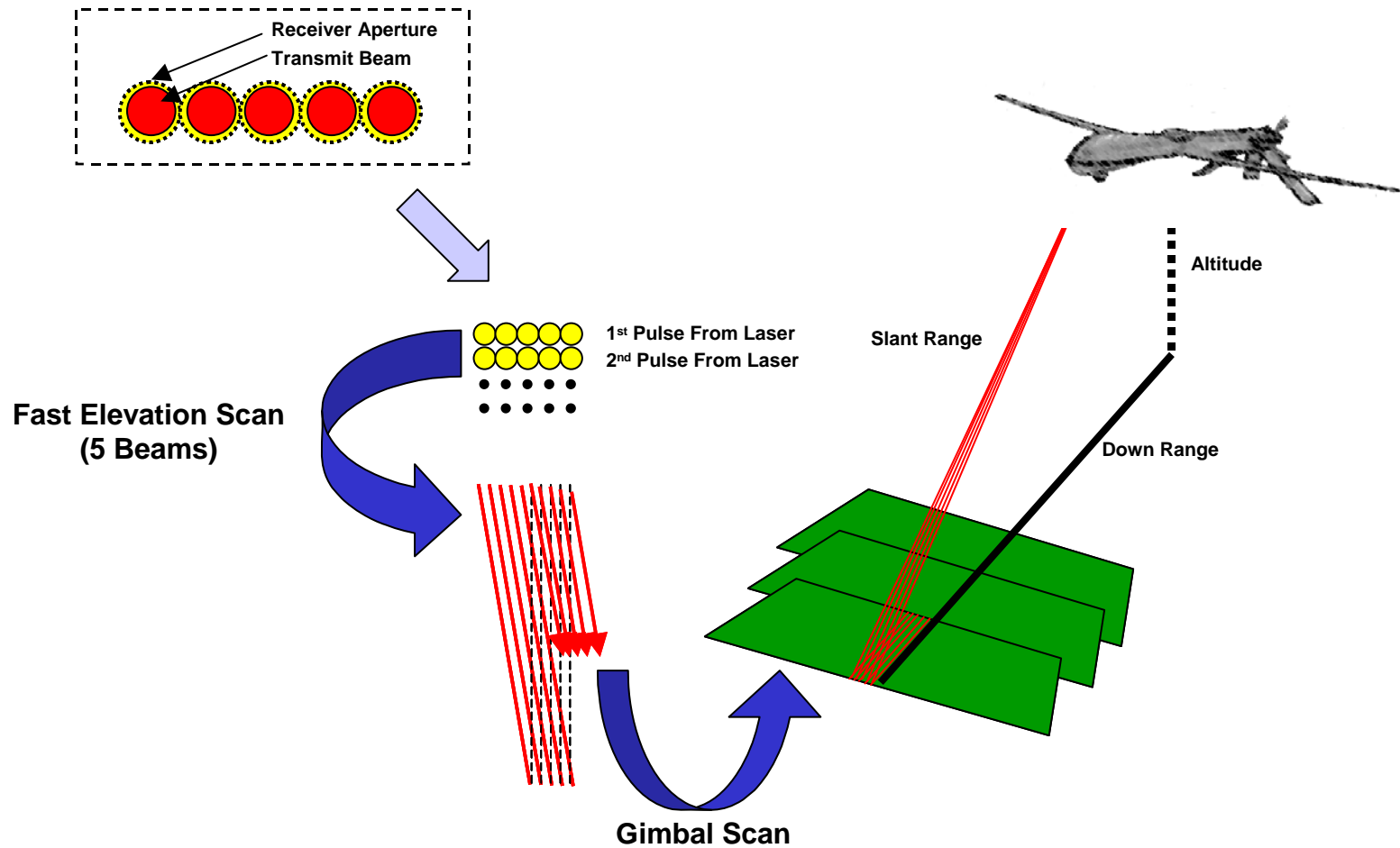
Flight Testing



The PILAR System Will Be Integrated On A Surrogate UAV Platform

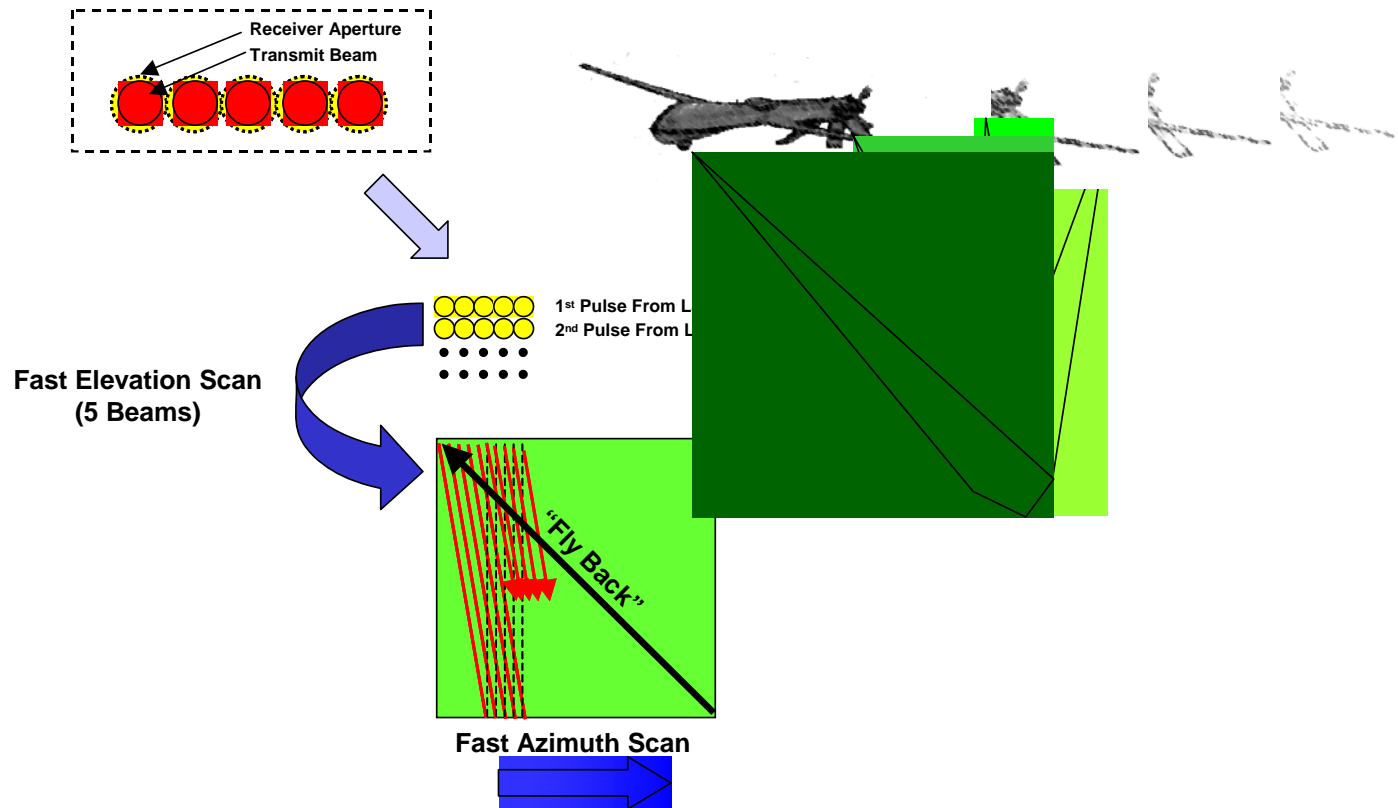


Terrain Mapping Mode





Targeting Mode





System Summary

- **High-Resolution 3-D Imaging:**
The optical system and pulse capture electronics provide true 3-D data to enable high-resolution imaging.
- **Imaging Of Targets Partially Obscured By Camouflage Or Foliage:**
Lockheed Martin's highly successful pulse signal processing technology is being exploited to provide a robust signal processing approach for PILAR.
- **High-Resolution Terrain Mapping:**
The LADAR sensor, controlled in coordination with the turret, provides the necessary capability to collect ground scans of high accuracy / high resolution 3-D data suitable for terrain mapping.
- **Polarimetry Information:**
The addition of a second receiver and a polarimetric beam splitter provides the LADAR sensor the capability to collect polarimetric data.
- **UAV Size And Weight Compatibility:**
The sensor was packaged into a 15-inch ball turret to make it suitable for UAV integration.



Program Summary

- **Risk Reduction Breadboard Currently Being Used To De-Bug Electronics And Software**
- **Turret Integration Was Completed Oct '04**
- **Tower Demonstrations Began in Nov '04**
- **First Flight June '05**